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Georges Bank Winter Flounder

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1.0 Background

The Georges Bank (GB) winter flounder stock was last assessed in September 2005 during a Groundfish Assessment Review Meeting (GARM) meeting (NEFSC 2005). The 2005 assessment represented an updated run of the SARC 34 ASPIC production model (Prager 2004), because the results of the VPA model runs were considered unreliable at SARC 34, primarily due to poorly sampled fishery length and age compositions during the terminal years of the assessment period (NEFSC 2002a). In 2005, the stock was not overfished, but overfishing was occurring.

The biological reference point estimates from the SARC 34 ASPIC model were also recommended for implementation by the 2002 Working Group on Re-estimation of Biological Reference Points for New England Groundfish (NEFSC 2002b). The estimates were: $F_{MSY} = 0.32$, $B_{MSY} = 9{,}400$ mt, and MSY = 3,000 mt. The 2002 Working Group concluded that the use of absolute reference point values from the ASPIC model (based on total biomass rather than exploitable biomass) is appropriate because the NEFSC surveys appear to measure the biomass of the exploitable portion of the stock. However, ASPIC-based biological reference points are re-estimated each time the model is run and model estimates of relative total biomass (B_t/B_{MSY}) and fishing mortality rates (F_t/F_{MSY}) are more precisely estimated than the absolute values (Prager 1995). Therefore, at the 2005 GARM, it was concluded that bias-corrected relative estimates of annual total biomass and fishing mortality rates from the updated ASPIC model run should be compared to relative biological reference points, a biomass threshold of 0.5 and a fishing mortality rate threshold of 1.0, to determine stock status. For the 2008 GARM, the use of an age-based Virtual Population Assessment model (VPA) is now possible as a result of improved biological sampling of the fishery and its use will avoid the pitfalls associated with prior use of the biomass-based ASPIC model to assess the Georges Bank winter flounder stock.

2.0 The Fishery

Landings

The stock boundary includes statistical areas 522-525, 542, 551-552 and 561-562. Commercial landings data are available for 1964-2006. During 1964 through May of 1994, U.S. commercial landings and fishery-related data were collected and entered into a Federal database by NMFS port agents. Since then, such data have been electronically reported by fish dealers and fishing location (statistical area) and fishing effort data related to landings are only available in the Vessel Trip Report database. As a result, the landings data and biological sampling data were allocated to statistical reporting areas based on Vessel Trip Report data using the method described in Wigley et al. (2007a). Recreational landings are insignificant.

A majority of the annual U.S. landings of GB winter flounder (92-100 %) are taken with bottom trawls. Total landings are also predominately from the U.S. bottom trawl fleet, but winter flounder landings have also been reported in the Canadian groundfish trawl fisheries (as bycatch in the haddock and cod fisheries). During 1964-1977, landings were also reported by the former USSR (Table K1, Figure K1). Canadian landings generally

comprised a low percentage (1-2 %) of the total landings until 1994, at which time Canadian landings increased from 6 % of the total to a peak of 24 % in 2001 (529 mt). The increasing trend in Canadian landings was concurrent with a Canadian prohibition on trawling for groundfish on Georges Bank during January-May. After 2001, Canadian landings declined and totaled 55 mt in 2006. Total landings increased during 1964-1972, reaching a peak of 4,500 mt in 1972, then declined to1,900 mt in 1976 (Figure K1, Table K1). A sustained period of high landings occurred during 1977-1984, ranging from 3,000-4,000 mt. After 1984, landings gradually declined to a time series low of 800 mt in 1995 then increased again to 3,100 mt in 2003. Thereafter, landings declined rapidly to 900 mt in 2006.

Length and age compositions of the landings are available for 1982-2006. A summary of the numbers of lengths sampled from the GB winter flounder landings, by year and market category group, is presented in Table A.K1 of the Appendix. Annual sampling intensity varied from 14 to 269 mt landed per 100 lengths measured during 1982-2006. Sampling intensity was lowest during 1996-2000, but improved substantially thereafter and was highest in recent years (2004-2006).

During most years, biological sampling of the landings was adequate to construct the landings at age (LAA) matrix on either a quarterly or half-year basis by market category group. The LAA matrix was constructed by applying commercial age-length keys to commercial numbers at length, on a quarterly, half-year or yearly basis, aggregated by market category group. The LAA matrix for 1982-1993 was constructed by Brown et al. (2000) and was updated for 1994-2006 using data from the allocation scheme noted above. The LAA matrix includes U.S. and Canadian landings during 1982-2006 (Table K2). The U.S. unclassified market category samples and the Canadian landings were assumed to have the same age compositions as the sampled U.S. landings and the LAA was adjusted accordingly to incorporate the Canadian landings.

Discards

Initial estimates of GB winter flounder discards, during 1964-2006, are provided for the large mesh bottom trawl fleet (codend mesh size ≥ 5.5 inches), small mesh groundfish fleet (codend mesh size < 5.5 inches), and the sea scallop dredge fleet ("limited permits" only) in Tables A.K2 and A.K3 of the Appendix. Discards (mt) for 1989-2006 were estimated based on fisheries observer data and the landings data using the combined ratio method described in Wigley et al. (2007b). The discard ratio estimator consisted of discards of GB winter flounder divided by the sum of all species kept by a particular fleet. Discards were estimated by quarter and cells with fewer than two trips were imputed using annual values (Table A.K4). Due to a lack of fisheries observer data, prior to 1989 for the trawl fleets and prior to 1992 for the scallop fleet, discard estimates were hindcast back to 1964 based on the following equation:

(1) $$\hat{D}_{t,h} = \bar{r}_{c,2003-2004,h} * K_{t,h}$$

where:

$\hat{D}_{t,h}$ is the annual discarded pounds of GB winter flounder for fleet *h* in year *t*

$\bar{r}_{c,2003-2004,h}$ is an average combined D/K ratio (discarded pounds of GB winter flounder / total pounds of all species kept) for the fleet *h* during either 2003-2004 (for the trawl fleets) or 1992-1998 (for the scallop dredge fleet)

$K_{t,h}$ is the total pounds of all species kept (landed) for fleet *h* in year *t*

During 1964-1974, discards were predominately attributable to the small mesh groundfish trawl fleet (Table A.K2). Thereafter, discards were primarily attributable to the scallop dredge fleet during most years. Discards ranged from 1-17 % of the total landings during 1964-2006. Total discards were higher during 1964-1991 than during 1992-2006 (Figure K2). Discards reached a peak of 381 mt in 1991 then declined sharply to their lowest level (1 mt) in 1995. Discards ranged between 9 and 85 mt during 1996-2003 and have been increasing since then, reaching 110 mt in 2006.

The annual number of lengths sampled from winter flounder discards in the bottom trawl and scallop dredge fisheries were inadequate to characterize discard length compositions during most years (Table A.K4). As a result, discards at age were characterized based on the following methods. Prior to specific trip limits on GB winter flounder, in May 2006, discards in the groundfish bottom trawl fishery were primarily comprised of fish smaller than the minimum size limit. The minimum size limit for GB winter flounder in the bottom trawl fishery was 28 cm during 1986-April, 1994 and has been 30 cm since then. Examination of NEFSC length-at-age data indicates that fish of this size are one year old in the NEFSC fall surveys and two years old in the spring surveys. Therefore, discards at age for the bottom trawl fleet, during 1982-2001, were estimated by dividing the estimated weight of discarded winter flounder from the bottom trawl fleet, during Jan.-June, by the annual mean weights of age 2 fish from the NEFSC spring surveys. Likewise, winter flounder discard weights for July-December were divided by the annual mean weights of age 1 fish from the NEFSC fall surveys. Discards at age for the bottom trawl fleet, during 2002-2006, were estimated by using the discard numbers at length for January-June or July-December to characterize the proportion discarded at length, and ages were determined by applying the NEFSC spring and fall age-length keys and survey length-weight relationships, respectively. The available discard length composition data for the scallop dredge fishery suggested that, in general, all sizes of winter flounder are discarded. Therefore, discards at age for the scallop dredge fishery were estimated by scaling up the LAA by the ratio of scallop dredge discards to total landings. During years when sufficient numbers of length samples of winter flounder discards were available, 1997 and 2004-2006, these length frequency distributions, for January-June or July-December, were used to characterize the proportion of discards at length for the scallop dredge fleet and ages were determined using the spring and fall survey age-length keys and length-weight relationships, respectively. There were no data available to estimate Canadian discards of GB winter flounder in either the groundfish trawl fleet, or more importantly, the scallop dredge fleet. The total discards at age matrix is presented in Table K3.

Catches

Catches increased during 1964-1972, reaching a peak of 4,600 mt in 1972, then declined to 2,000 mt in 1976 (Figure K2, Table K1). Catches subsequently increased to 4,300 mt in 1981 then gradually declined to a time series low of 800 mt in 1995. Catches increased to 3,100 mt in 2003 then declined to 990 mt in 2006. Historical catches are likely to have been higher than those observed during 1964-2006 because the lemon sole (fish < 1.36 kg) component of the landings alone reached a peak of 4,089 mt in 1945 (Figure K3).

The catch at age (CAA) input to the VPA consisted of combined U.S. and Canadian landings at age and discards at age for the U.S. large and small groundfish bottom trawl fleets and the scallop dredge fleet, during 1982-2006, for ages 1-6 with a 7+ age group (Table K4). Trends in mean weights at age in the catch remained relatively stable between 1982 and 1996 then declined through 1998 for ages 3-5 and became more variable for older age groups, likely due to poor sampling (Figure K4). However, since 2000/2001, mean weights in the catch have been increasing for all age groups except age one, but particularly for ages 4 and older.

3.0 Research Survey Data

Relative biomass (stratified mean kg per tow) and abundance (stratified mean number per tow) indices are available for the NEFSC spring (April, 1968-2007) and autumn (October, 1963-2007) bottom trawl surveys (offshore strata 13-23), as well the Canadian spring bottom trawl surveys (February, 1987-2007), for strata 5Z1-Z4 (Table K5). The NEFSC survey indices were revised to include offshore strata 13-23 rather than the strata set from previous assessments (strata 13-22) because a high proportion of fish in stratum 23 exhibit Georges Bank-type growth patterns which are much more rapid than those of the other two winter flounder stocks. The addition of fish from stratum 23 mainly affects the fall survey indices because winter flounder densities in stratum 23 are low during spring (Figure A.K1). NEFSC survey indices prior to 1985 were standardized for gear changes (weight = 1.86 and numbers = 2.02, Sissenwine and Bowman 1978) and trawl door changes (weight = 1.39 and numbers = 1.4, Byrne and Forrester 1991).

Despite considerable interannual variability, the NEFSC fall survey relative abundance indices indicate an increasing trend during the 1970's followed by a declining trend during the 1980s, to a time series low in 1991 (Figure K5, Table K5). Thereafter, relative abundance increased through 2002 then declined and was below the 1963-2006 median during 2005-2007. Relative abundance indices from the NEFSC spring surveys exhibited more interannual variability but showed trends similar to the fall survey series after 1982. Trends in relative abundance indices from the Canadian survey showed trends similar to the NEFSC spring survey during most years but were of greater magnitude during blocks of years (1988-1990 and 1993-1997). Relative abundance indices from the Canadian surveys were at the lowest levels observed during 2006 and 2007.

Stratified mean number per tow at age indices are presented for the U.S. fall (1981-2006, ages 0-6 lagged forward one year and age) and spring bottom trawl surveys (1968-2006) and the Canadian spring bottom trawl surveys (1987-2006) in Tables K5, K6, and K7,

respectively. Age samples are not collected during Canadian bottom trawl surveys so the NEFSC spring survey age-length keys, augmented during some years with commercial age-length keys from the first quarter of the corresponding year (when larger fisher were caught), were used to partition stratified mean numbers at length from the Canadian surveys into numbers at age. Although the indices are highly variable, large cohorts appear to track through the numbers at age matrices for the 1980, 1987, 1994, and 1998-2001 cohorts (Figure K6). Age truncation occurred between 1983 and 1997 during which time the population was dominated by four age groups rather than seven or more. During 1997-2004, the age structure improved but has since become truncated again. Both the U.S. and Canadian spring surveys show reduced abundances of age 1-3 fish (and age 4 fish in the CA surveys) after 2000.

The VPA maturity at age matrix was constructed using a five-year moving window for maturity data from the NEFSC spring surveys conducted during 1982-2006. The A_{50} is approximately 2 years and all fish are mature by age 4, and in recent years, by age 3 (Table K9).

4.0 Assessment

Input Data and Analyses

The catch at age input to the VPA consisted of combined U.S. and Canadian landings during 1982-2006 for ages 1-6 with a 7+ age group. The VPA was calibrated with stratified mean number per tow at age indices from the U.S. spring (1968-2006, ages 1-7) and fall bottom trawl surveys (1981-2006, ages 0-6 lagged forward one year and age) and the Canadian spring bottom trawl surveys (1987-2006, ages 1-7). Stock sizes were estimated for ages 2-6 in the terminal year+1.

Precision of the 2006 spawning stock biomass and fully recruited fishing mortality were derived from 1,000 bootstrap replicates of the VPA. Retrospective analyses of terminal year estimates of age 1 recruitment, fully recruited fishing mortality, and SSB were also carried out back to 1993.

Results

VPA estimates of Jan. 1 population size (numbers, 000's), fishing mortality rates, and spawning stock biomass (mt) are presented in Tables K10-12, respectively. Fishing mortality (average F for fully recruited fish, ages 4-6) was highest during 1984-1993, ranging between 0.65 and 1.32, then declined to levels ranging between 0.38 and 0.64 during 1994-1998 (Figure K7A, Table K13). Fishing mortality was low (0.32) during 1999 and 2000 then increased rapidly to 0.97 in 2003 and was followed by a rapid decline to a record low of 0.27 in 2006. SSB declined rapidly from a time series peak of 15,600 mt in 1982 to 5,800 mt in 1985, and then increased slightly through 1987 to 7,800 mt. After 1987, SSB declined again to a time series low of 3,300 mt in 1994. SSB subsequently increased to 11,600 mt in 2000, but then declined to 4,300 mt in 2006 (Figure K7B). Trends in age 1 recruitment (numbers) indicate two periods of rise-and-fall. Recruitment increased from 5.9 million fish in 1983 to a time series peak of 18.6 million fish in 1988, and then declined to 3.4 million fish in 1993 (Figure K7C). Recruitment increased again to fairly high levels during 1995-1999 (9.9-14.6

million fish) then declined to the lowest level on record (2 million fish) in 2005. Recruitment of age 1 fish in 2007 is estimated to be low (4 million fish) and similar to the 2004 level, but the estimate is uncertain because it is based solely on survey indices.

VPA Diagnostics

Residuals patterns were evident for some of the VPA calibration indices at age. For example, residuals patterns were negative for relative abundance indices of age 3 fish from the NEFSC spring surveys, during 2001-2007, and for age 3 and 4 fish from the Canadian spring surveys during 1998-2007 (Figure K8). The residuals were positive for age 5 and 6 fish (age 4 and 5 fish lagged forward one year and age) in the NEFSC fall surveys during 2002/2003-2007. Survey catchabilities are presented in Table K14.

Bootstrap results suggest that the 2006 estimates of fully recruited average F (ages 4-6) and spawning stock biomass are fairly precise with CVs of 25 % and 19 %, respectively. There is an 80% probability that average F for ages 4-6 in 2006 was between 0.21 and 0.37. There is an 80% probability that SSB in 2006 was between 3,498 and 5,655 mt.

Very mild retrospective patterns were present for terminal year estimates of fishing mortality rates (underestimation of F) and spawning stock biomass (overestimation of SSB, Figure K9A and B). There was no retrospective pattern for terminal year age 1 recruitment, but the estimates were highly variable (Figure K9C).

In order to determine whether omitting certain tuning indices would remove the observed residuals patterns and improve the retrospective pattern, the following additional VPA formulations were run: all indices except the CA series; all indices except ages 1-3 in the CA series; NEFSC spring surveys ages 4-7 plus fall surveys ages 1-7; and all indices except the CA series and ages 1-3 from the fall surveys. However, all of these runs resulted in worse retrospective patterns and shifted the residuals patterns to other ages and years. A VPA run involving a pre- and post-1994 split for all of the survey time series has removed retrospective patterns for GB yellowtail flounder. However, such a run resulted in very strong retrospective patterns in F and SSB, probably because 1994 was not a problematic year for the GB winter flounder stock with respect to residuals patterns.

5.0 Biological Reference Points

Both a Beverton-Holt stock-recruitment model (Beverton and Holt 1957) and a YPR and SSB/R model (Thompson and Bell 1934) were used to estimate F_{MSY} and an F_{MSY} proxy of $F_{40\%}$, respectively. Stock-recruitment data were modeled for the 1981-2005 year classes (1981-2005 SSB and1982-2006 recruitment at age 1 from the VPA). The 2006 SSB data were not included in the calculations due to the uncertainty of the 2007 age 1 estimate. Input data for the YPR and SSB/R model included the fishery selectivity and vector from the VPA, the 2005 five-year moving window of the proportion mature at age, and the 2002-2006 averages of mean catch weights, mean stock weights, and spawning stock weights from the

VPA results (Table K15). The yield-per-recruit and SSB-per-recruit analysis resulted in an F_{MSY} proxy estimate for $F_{40\%}$ of 0.25 (Table K16).

The Beverton-Holt stock-recruitment model was run using version 6.3 of the SRFIT software provided in version 3.0 of the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/). SSB and R data from the VPA were input for the 1981-2005 year classes. The Beverton-Holt function required setting a prior (= 15,980,000 fish, SE = 500) on unfished recruitment, equal to the average of the three highest recruitment estimates during 1963-2006, because the lack of such a prior resulted in a steepness value of 1.0. In order to provide an estimate for the prior, hindcast estimates of recruitment were derived for 1963-1981 from a linear regression of the 1982-2006 age 1 recruitment estimates from the VPA (numbers) against the 1982-2006 stratified mean numbers per tow of age 1 fish from the NEFSC fall surveys ($r^2 = 0.32$). The predicted stock-recruitment relationship from the Beverton-Holt model and standardized model residuals are presented in Figure K10. F_{MSY} was estimated as 0.33.

Long-term (100-year) stochastic projections were run using AGEPRO software (v. 3.13) from the NOAA Fisheries Toolbox under two constant harvest scenarios, $F_{40\%}$ (= 0.25) and F_{MSY} (= 0.33), to predict median MSY and SSB_{MSY} under equilibrium conditions. Both projections included the data presented in Table K15. The constant F_{MSY} scenario projection assumed recruitment is dependent on stock size and included S-R parameter estimates and variance estimate from the Beverton-Holt stock-recruitment model (α = 17,117, β = 5029, and δ = 0.6129) and assumed lognormal error. The $F_{40\%}$ scenario projection was based on the empirical cumulative distribution function of age 1 recruitment from the VPA and assumed that recruitment is independent of stock size. Median SSB_{MSY} and MSY estimates from the $F_{40\%}$ run were 15,500 mt and 3,400 mt, respectively, and for the F_{MSY} run were 27,000 mt and 7,500 mt, respectively (Figure K11, Table K16).

6.0 Literature Cited

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7.0 Acknowledgements

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Table K1. Landings, discards, and catches (mt) of Georges Bank winter flounder during 1964-2006.

YEAR	522-525 561-562 USA[1]	5Ze[2] (521-526 and 541-562) CANADA	5Ze[2] (521-526 and 541-562) USSR	5Z (521-562) CANADA	5Z (521-562) USSR	TOTAL LANDINGS	DISCARDS	TOTAL CATCH
1964	1,370			146		1,516	231	1,747
1965	1,175			199	312	1,686	165	1,851
1966	1,876			164	156	2,196	137	2,333
1967	1,916			83	349	2,348	106	2,454
1968	1,569	57	372			1,998	140	2,138
1969	2,165	116	235			2,516	117	2,633
1970	2,613	61	40			2,714	109	2,824
1971	3,089	62	1,029			4,180	105	4,286
1972	2,802	8	1,699			4,509	98	4,608
1973	2,267	14	693			2,974	94	3,068
1974	2,123	12	82			2,217	98	2,315
1975	2,407	13	515			2,935	118	3,053
1976	1,876	15	1			1,892	142	2,034
1977	3,569	15	7			3,591	207	3,798
1978	3,183	65				3,248	262	3,510
1979	3,042	19				3,061	257	3,319
1980	3,928	44				3,972	255	4,227
1981	3,990	19				4,009	281	4,290
1982	2,959	19				2,978	246	3,224
1983	3,894	14				3,908	225	4,133
1984	3,927	4				3,931	195	4,126
1985	2,151	12				2,163	158	2,321
1986	1,761	25				1,786	182	1,968
1987	2,637	32				2,669	272	2,941
1988	2,804	55				2,859	293	3,152
1989	1,880	11				1,891	316	2,207
1990	1,898	55				1,953	338	2,291
1991	1,814	14				1,828	314	2,142
1992	1,822	27				1,849	29	1,877
1993	1,662	21				1,683	11	1,693
1994	931	65				996	10	1,005
1995	729	54				783	1	784
1996	1,370	71				1,441	26	1,467

YEAR	522-525 561-562 USA[1]	5Ze[2] (521-526 and 541-562) CANADA	5Ze[2] (521-526 and 541-562) USSR	5Z (521-562) CANADA	5Z (521-562) USSR	TOTAL LANDINGS		CATCH
1997	1,226	143				1,369	69	1,438
1998	1,308	93				1,401	52	1,453
1999	939	104				1,043	85	1,128
2000	1,603	161				1,764	65	1,829
2001	1,674	529				2,203	11	2,214
2002	2,100	244				2,344	20	2,364
2003	2,829	310				3,139	9	3,149
2004	2,660	191				2,851	69	2,921
2005	2,012	73				2,085	118	2,202
2006	825	55				880	110	990

[1] USA landings prior to 1985 include those from Statistical Areas 551 and 552, and since May of 1994, landings have been self-reported by dealers and were allocated to statistical areas based on Vessel Trip Report data.

[2] Includes landings from statistical areas 521, 526, and 541 which are outside of the Georges Bank winter flounder stock area.

Table K2. Landings (numbers, in thousands) at age for Georges Bank winter flounder during 1982-2006.

	Age						
Year	1	2	3	4	5	6	7+
1982	0	353	1,707	1,048	511	258	281
1983	10	787	2,902	1,454	551	206	528
1984	0	282	570	1,371	1,408	635	920
1985	20	805	693	812	491	112	100
1986	0	665	1,328	235	229	131	88
1987	0	1,294	1,681	899	133	89	121
1988	0	835	2,774	843	197	90	93
1989	0	1,381	1,222	509	147	107	61
1990	0	295	2,032	668	185	46	17
1991	0	593	1,270	951	136	38	60
1992	0	796	756	727	468	92	61
1993	37	301	1,143	451	320	163	47
1994	0	367	635	360	97	50	45
1995	371	701	172	142	105	32	41
1996	0	1,319	423	185	95	98	88
1997	0	355	993	444	176	79	87
1998	0	10	1,426	826	131	43	12
1999	0	296	786	521	147	20	20
2000	0	646	1,108	369	254	186	160
2001	11	372	1,280	801	586	158	99
2002	0	121	927	757	445	236	189
2003	0	259	694	925	455	252	400
2004	0	62	579	844	520	234	367
2005	0	224	529	752	362	142	217
2006	0	25	283	278	122	55	113

Table K3. Discards (numbers, in thousands) at age for Georges Bank winter flounder during 1982-2006.

				Age			
Year	1	2	3	4	5	6	7+
1982	116	692	1,776	1,090	531	268	292
1983	137	1,037	3,000	1,503	570	213	546
1984	138	427	587	1,412	1,450	654	947
1985	66	946	733	858	519	118	106
1986	38	763	1,416	251	244	139	94
1987	99	1,461	1,789	956	142	94	129
1988	72	1,013	2,925	889	208	95	98
1989	34	1,556	1,340	559	161	117	66
1990	36	370	2,248	739	204	50	18
1991	2	656	1,389	1,040	149	41	66
1992	23	764	704	678	436	86	57
1993	39	285	1,062	419	297	152	44
1994	8	353	598	339	92	47	43
1995	365	688	168	138	103	31	40
1996	35	1,336	424	185	95	98	88
1997	1	49	27	12	2	1	1
1998	0	10	1,445	837	132	44	12
1999	70	395	808	536	151	20	21
2000	52	676	1,100	366	253	185	159
2001	15	376	1,276	799	584	157	99
2002	0	117	890	728	427	227	182
2003	0	257	689	918	452	251	398
2004	1	7	5	17	5	3	7
2005	2	36	16	19	11	18	12
2006	0	7	18	22	24	6	7

Table K4. Catch (numbers, in thousands) at age for Georges Bank winter flounder during 1982-2006.

	Age						
Year	1	2	3	4	5	6	7+
1982	116	1,045	3,483	2,138	1,042	526	573
1983	147	1,824	5,902	2,957	1,121	419	1,075
1984	138	709	1,157	2,783	2,859	1,289	1,867
1985	86	1,751	1,426	1,670	1,010	229	206
1986	38	1,428	2,744	486	472	270	182
1987	99	2,755	3,470	1,855	275	183	250
1988	72	1,848	5,699	1,731	405	184	192
1989	34	2,936	2,562	1,068	309	224	127
1990	36	665	4,280	1,408	389	96	35
1991	2	1,248	2,659	1,990	284	79	126
1992	23	1,560	1,460	1,405	904	178	118
1993	76	585	2,205	870	617	315	90
1994	8	720	1,232	699	189	96	88
1995	736	1,388	340	280	209	63	80
1996	35	2,655	846	370	190	196	176
1997	1	404	1,020	456	179	80	87
1998	0	20	2,870	1,662	263	87	25
1999	70	691	1,595	1,057	298	40	41
2000	52	1,322	2,208	735	507	371	319
2001	26	748	2,556	1,600	1,170	315	198
2002	0	238	1,816	1,485	872	463	371
2003	0	517	1,383	1,843	908	504	797
2004	1	69	584	861	525	237	374
2005	2	260	545	771	373	160	229
2006	0	32	301	300	146	61	120

Table K5. Relative abundance (mean number per tow) and biomass (mean kg per tow) indices for Georges Bank winter flounder caught in the U.S. spring and autumn (strata 13-23) and Canada spring (strata 5Z1-5Z4) research vessel bottom trawl surveys. Standardization coefficients for trawl door changes (numbers = 1.46 and weight = 1.39) and gear changes (numbers = 2.02 and weight = 1.86) were applied to NEFSC survey indices.

Year	U.S. Spring Survey		U.S. Autumn Survey		Canada Spring Survey	
	Number/tow	Kg/tow	Number/tow	Kg/tow	Number/tow	Kg/tow
1963			1.94	3.02		
1964			1.75	2.77		
1965			2.70	3.03		
1966			4.79	5.26		
1967			1.78	2.11		
1968	2.66	2.99	1.92	1.83		
1969	2.95	4.02	2.59	2.53		
1970	1.81	2.20	7.02	7.73		
1971	1.71	2.04	1.53	1.32		
1972	4.71	4.90	1.64	1.56		
1973	1.34	1.73	2.56	2.30		
1974	3.19	3.16	1.36	1.55		
1975	0.92	0.72	3.74	2.09		
1976	2.23	1.57	5.52	3.63		
1977	1.95	0.90	4.81	3.97		
1978	3.25	2.52	4.22	3.47		
1979	0.79	1.09	5.06	4.08		
1980	1.63	1.45	2.03	2.32		
1981	1.92	2.00	5.50	4.41		
1982	2.42	1.57	5.61	3.32		
1983	8.29	6.93	3.03	2.89		
1984	5.12	5.22	4.90	3.28		
1985	3.54	2.44	1.98	1.18		
1986	2.10	1.26	3.31	2.00		
1987	2.61	1.16	0.96	1.03	1.24	1.74
1988	2.68	1.51	3.90	1.29	4.31	2.75
1989	1.25	0.73	1.43	0.96	4.05	1.95
1990	2.65	1.48	0.51	0.34	4.93	2.64
1991	2.21	1.21	0.31	0.24	1.98	1.38
1992	1.34	0.83	0.69	0.38	0.51	0.59
1993	1.00	0.58	1.22	0.78	3.53	1.76
1994	1.25	0.56	0.85	0.56	5.10	2.01
1995	2.42	1.38	2.74	1.62	5.63	1.96
1996	2.12	1.38	1.48	1.68	4.12	2.30

Table K5 (cont.)

Year	U.S. Spring Survey		U.S. Autumn Survey		Canada Spring Survey	
	Number/tow	Kg/tow	Number/tow	Kg/tow	Number/tow	Kg/tow
1997	1.48	1.09	1.78	1.55	4.58	3.09
1998	0.78	0.71	3.50	3.40	1.14	1.21
1999	3.56	3.21	2.45	2.47	1.25	1.89
2000	4.25	3.55	4.60	4.82	1.48	2.22
2001	1.25	1.16	6.08	4.85	2.28	2.54
2002	4.73	4.82	4.67	5.60	3.17	3.85
2003	1.22	1.30	2.36	2.96	1.09	1.31
2004	0.42	0.51	5.01	4.06	2.10	1.79
2005	1.00	0.80	1.94	2.11	1.19	1.23
2006	0.58	0.49	1.36	1.42	0.09	0.17
2007	0.75	0.68	2.13	2.00	0.18	0.27
Grand Mean	2.30	1.95	2.92	2.57	2.57	1.84

Table K6. NEFSC fall survey stratified mean numbers per tow at age for Georges Bank winter flounder (offshore strata 13-23). Numbers at age include data for 1981-2006 lagged forward one year and age.

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
1982		2.1742	0.6121	0.7387	0.9817	0.4576	0.1221	0.2210	0.1337	0.0575
1983	0.2581	1.9002	1.9769	0.5287	0.4919	0.2567	0.1669		0.0303	
1984	0.0241	0.0632	0.5155	1.2226	0.5614	0.2141	0.2395	0.0866	0.0516	0.0514
1985	0.2167	0.5938	1.0793	1.2623	1.2780	0.3342	0.1026	0.0237	0.0112	
1986	0.0994	0.3093	0.8036	0.4988	0.0724	0.1723	0.0249			
1987	0.1316	1.0528	1.4765	0.3358	0.1860	0.0439	0.0221	0.0213		0.0439
1988	0.0329	0.0483	0.2169	0.2325	0.1890	0.0902	0.0724	0.0563	0.0241	
1989	0.0442	2.6845	0.5627	0.4248	0.1257	0.0082	0.0228	0.0228		
1990	0.0221	0.0884	0.9729	0.0659	0.1297	0.0669	0.0527	0.0086	0.0241	
1991	0.0221	0.0551	0.0403	0.3416		0.0468				
1992	0.0989	0.0419		0.0733	0.0483	0.0165	0.0329			
1993		0.0485	0.4618	0.1438	0.0086	0.0241				
1994		0.5377	0.1740	0.2566	0.1933	0.0241		0.0165		0.0165
1995		0.1512	0.3845	0.2036	0.0780	0.0303				
1996	0.0165	0.8506	1.0121	0.6215	0.1697	0.0521			0.0165	
1997		0.1125	0.3120	0.5574	0.2348	0.1186	0.0857	0.0569		
1998	0.0165	0.0717	0.5885	0.6883	0.3118	0.0721	0.0268	0.0029		
1999	0.0824	0.2480	0.3502	1.5549	1.0061	0.1725	0.0598	0.0241		
2000	0.0165	0.3519	0.7221	0.3455	0.3329	0.5521	0.0803	0.0241	0.0221	
2001	0.0165	0.0483	1.1667	1.5118	0.6833	0.8189	0.2451	0.0506	0.0625	
2002	0.0165	0.5437	1.3940	2.2159	1.1577	0.2925	0.3011	0.0905	0.0483	0.0228
2003		0.1873	0.4499	0.9558	1.1884	1.0416	0.3722	0.4330	0.0212	0.0212
2004	0.2803	0.1598	0.0247	0.3199	0.6984	0.5921	0.1897	0.0727	0.0193	
2005	0.2094	0.2960	1.2277	1.2500	1.2048	0.2561	0.3169	0.2086	0.0402	
2006	0.0881	0.0495	0.1519	0.4476	0.4211	0.2692	0.3249	0.1195	0.0165	0.0528
2007		0.0914	0.1623	0.2790	0.3446	0.3828	0.0654	0.0377		

Table K7. NEFSC spring survey stratified mean numbers per tow at age for Georges Bank winter flounder (offshore strata 13-23) during 1982-2007.

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
1982	0.0675	0.8192	0.5035	0.5990	0.1737	0.1374	0.0376	0.0161	0.0323	0.0323
1983	0.0241	0.9412	3.3611	1.4108	0.6282	0.7221	0.5515	0.3850	0.1131	0.1532
1984	0.0323	0.1529	1.9118	1.4839	0.3541	0.3440	0.4332	0.2538	0.0241	0.1322
1985		1.5435	0.7454	0.5768	0.3644	0.2025	0.0427	0.0221	0.0442	
1986	0.2312	0.6821	0.7780	0.1742	0.1544	0.0767				
1987	0.1478	1.4946	0.6084	0.2496	0.0828		0.0221			
1988	0.0663	0.5042	1.3002	0.6283	0.1066	0.0379	0.0165		0.0241	
1989	0.0442	0.5082	0.2657	0.2278	0.1428	0.0165		0.0483		
1990	0.1171	0.5923	1.4625	0.3242	0.0895	0.0672				
1991	0.2480	0.3163	0.7565	0.5324	0.2525	0.0331	0.0221		0.0442	
1992	0.0663	0.5916	0.2743	0.1277	0.1339	0.1004		0.0221	0.0241	
1993	0.1564	0.2639	0.3284	0.1590		0.0425	0.0302	0.0221		
1994	0.1154	0.5485	0.3953	0.0875	0.0598	0.0406				
1995	0.1364	0.7173	1.1750	0.2693	0.0931	0.0268				
1996	0.0342	1.1187	0.3957	0.4486	0.0632	0.0241	0.0386			
1997	0.0221	0.1764	0.4915	0.6141	0.1046	0.0221	0.0241		0.0221	
1998		0.0214	0.1982	0.4243	0.1138		0.0241			
1999	0.2038	0.4972	0.6126	1.1913	0.8131	0.1815	0.0483	0.0165		
2000	0.0165	0.5630	0.9700	0.6326	1.0485	0.6658	0.1818	0.1093	0.0646	
2001		0.0660	0.3042	0.2854	0.1785	0.1754	0.2432			
2002	0.1028	0.1512	0.2226	1.7563	0.7009	0.7117	0.6363	0.2827	0.1446	0.0236
2003	0.0468	0.0247	0.1480	0.2095	0.3333	0.2905	0.1398	0.0241		
2004		0.0330	0.0241	0.0571	0.1952	0.0665	0.0214	0.0251		
2005	0.0889	0.1702	0.1177	0.2860	0.1922	0.1197		0.0241		
2006	0.0386		0.1709	0.1903	0.0796	0.0738		0.0221		
2007	0.0828	0.1158	0.0607	0.1443	0.1631	0.0905	0.0511	0.0208	0.0171	

Table K8. Canada spring (February) survey stratified mean numbers per tow at age for Georges Bank winter flounder (strata 5Z1-5Z4) during 1987-2007.

	Age									
Year	1	2	3	4	5	6	7	8	9	10+
1987		0.1089	0.2436	0.3207	0.4057	0.1618				
1988	0.1628	0.6138	2.2198	1.0383	0.1610	0.0737		0.0365		
1989	0.0861	1.9788	0.9910	0.7122	0.2235	0.0422	0.0110	0.0095		
1990		0.1402	1.0859	3.1660	0.4163	0.0661	0.0401	0.0054		
1991	0.0694	0.0909	0.6548	0.9181	0.2051	0.0453				
1992		0.0269	0.0597	0.2088	0.0759	0.1368		0.0051		
1993	1.1855	0.6668	0.9465	0.4488	0.1345	0.0764	0.0653	0.0048		
1994	0.0154	3.3119	1.1211	0.2457	0.3713	0.0010	0.0174	0.0163		
1995	1.5778	2.4547	1.2702	0.2126	0.0905	0.0122	0.0025			
1996	0.8943	1.2590	0.9359	0.6489	0.2163	0.0790	0.0771	0.0025	0.0046	0.0066
1997	0.0172	0.9682	1.5735	1.7518	0.1902	0.0360	0.0142	0.0278		
1998	0.0183	0.0297	0.1597	0.6075	0.2862	0.0339				
1999	0.0505	0.2448	0.2328	0.4006	0.2303	0.0574	0.0192	0.0061	0.0056	
2000	0.0098		0.0105	0.1391	0.1307	0.3604	0.3615	0.1912	0.1919	0.0865
2001	0.2392	0.0786	0.1931	0.2333	0.4382	0.1465	0.3692	0.5534	0.0162	0.0179
2002		0.0916	0.2162	0.0817	1.1585	0.4067	0.4288	0.4520	0.2007	0.1324
2003	0.0463	0.2144	0.0595	0.0847	0.1270	0.2076	0.1372	0.2003	0.0110	0.0036
2004	0.5260	0.1795	0.0944	0.2196	0.2160	0.5202	0.1602	0.1534	0.0276	
2005	0.0876	0.1588	0.0876	0.1657	0.1709	0.1702	0.1622	0.1005	0.0589	0.0271
2006		0.0053	0.0053	0.0577	0.0575	0.0528	0.1087	0.0036	0.0041	0.0009
2007			0.0048		0.0132	0.0623	0.0385	0.0331	0.0130	0.0138

Table K9. Georges Bank winter flounder maturity at age matrix input to the VPA based on a five-year moving window of the proportion of fish mature at age in the NEFSC spring bottom trawl surveys, 1982-2006.

	Age						
Year	1	2	3	4	5	6	7+
1982	0.11	0.45	0.85	0.98	1.00	1.00	1.00
1983	0.04	0.32	0.83	0.98	1.00	1.00	1.00
1984	0.08	0.41	0.85	0.98	1.00	1.00	1.00
1985	0.22	0.59	0.88	0.97	1.00	1.00	1.00
1986	0.05	0.65	0.98	1.00	1.00	1.00	1.00
1987	0.05	0.61	0.98	1.00	1.00	1.00	1.00
1988	0.05	0.65	0.98	1.00	1.00	1.00	1.00
1989	0.04	0.61	0.98	1.00	1.00	1.00	1.00
1990	0.01	0.37	0.97	1.00	1.00	1.00	1.00
1991	0.03	0.50	0.97	1.00	1.00	1.00	1.00
1992	0.06	0.58	0.97	1.00	1.00	1.00	1.00
1993	0.06	0.55	0.96	1.00	1.00	1.00	1.00
1994	0.09	0.61	0.96	1.00	1.00	1.00	1.00
1995	0.05	0.68	0.99	1.00	1.00	1.00	1.00
1996	0.07	0.65	0.98	1.00	1.00	1.00	1.00
1997	0.00	0.70	1.00	1.00	1.00	1.00	1.00
1998	0.00	0.78	1.00	1.00	1.00	1.00	1.00
1999	0.10	0.71	0.98	1.00	1.00	1.00	1.00
2000	0.08	0.72	0.99	1.00	1.00	1.00	1.00
2001	0.07	0.72	0.99	1.00	1.00	1.00	1.00
2002	0.06	0.58	0.97	1.00	1.00	1.00	1.00
2003	0.05	0.51	0.95	1.00	1.00	1.00	1.00
2004	0.00	0.64	1.00	1.00	1.00	1.00	1.00
2005	0.00	0.44	1.00	1.00	1.00	1.00	1.00
2006	0.00	0.44	1.00	1.00	1.00	1.00	1.00

Table K10. VPA estimates of Jan. 1 population size (numbers, 000's) for Georges Bank winter flounder, 1982-2007.

AGE	1982	1983	1984	1985	1986
1	9809.	5883.	12718.	12243.	16441.
2	16952.	7926.	4684.	10288.	9946.
3	13082.	12936.	4849.	3196.	6847.
4	6881.	7583.	5320.	2930.	1343.
5	2557.	3715.	3561.	1876.	914.
6	1561.	1161.	2036.	411.	637.
7	1701.	2979.	2949.	369.	429.
Total	52542.	42183.	36118.	31314.	36557.

AGE	1987	1988	1989	1990	1991
1	11144.	18563.	10204.	6869.	8953.
2	13426.	9035.	15133.	8323.	5591.
3	6857.	8514.	5735.	9749.	6215.
4	3150.	2520.	1928.	2406.	4157.
5	664.	931.	533.	628.	719.
6	328.	298.	400.	162.	169.
7	448.	311.	227.	59.	270.
Total	36018.	40173.	34161.	28197.	26074.

AGE	1992	1993	1994	1995	1996
1	4367.	3412.	5219.	14566.	10718.
2	7329.	3555.	2725.	4265.	11261.
3	3456.	4597.	2384.	1585.	2247.
4	2711.	1524.	1796.	854.	992.
5	1627.	968.	474.	845.	448.
6	334.	528.	245.	219.	504.
7	222.	151.	225.	278.	452.
Total	20046.	14735.	13068.	22611.	26622.

AGE	1997	1998	1999	2000	2001
1	9935.	12247.	12503.	9920.	5970.
2	8744.	8133.	10026.	10173.	8075.
3	6833.	6794.	6641.	7585.	7138.
4	1083.	4676.	2996.	4004.	4228.
5	480.	479.	2339.	1506.	2616.
6	197.	233.	158.	1647.	778.
7	214.	67.	162.	1416.	489.
Total	27486.	32629.	34824.	36251.	29295.

AGE	2002	2003	2004	2005	2006	2007
1	4944.	3230.	4393.	1966.	4948.	3996.
2	4864.	4048.	2644.	3596.	1607.	4050.
3	5937.	3768.	2848.	2102.	2710.	1287.
4	3554.	3231.	1846.	1806.	1232.	1947.
5	2029.	1582.	1007.	743.	790.	739.
6	1097.	882.	488.	357.	275.	515.
7	879.	1394.	770.	510.	559.	522.
Total	23304.	18135.	13996.	11080.	12120.	13057.

Table K11. VPA estimates of fishing mortality rates, by year and age, for Georges Bank winter flounder, 1982-2006.

AGE	1982	1983	1984	1985	1986
1	0.0131	0.0279	0.0120	0.0078	0.0026
2	0.0704	0.2913	0.1821	0.2072	0.1719
3	0.3454	0.6886	0.3037	0.6672	0.5762
4	0.4162	0.5557	0.8423	0.9648	0.5041
5	0.5894	0.4015	1.9600	0.8807	0.8254
6	0.4603	0.5023	1.1568	0.9311	0.6221
7	0.4603	0.5023	1.1568	0.9311	0.6221

AGE	1987	1988	1989	1990	1991
1	0.0098	0.0043	0.0037	0.0058	0.0002
2	0.2555	0.2545	0.2398	0.0921	0.2812
3	0.8008	1.2851	0.6685	0.6524	0.6296
4	1.0188	1.3527	0.9212	1.0081	0.7379
5	0.6021	0.6439	0.9911	1.1110	0.5653
6	0.9326	1.1072	0.9359	1.0285	0.7105
7	0.9326	1.1072	0.9359	1.0285	0.7105

AGE	1992	1993	1994	1995	1996
1	0.0058	0.0249	0.0017	0.0573	0.0036
2	0.2663	0.1996	0.3423	0.4407	0.2995
3	0.6188	0.7398	0.8267	0.2688	0.5305
4	0.8302	0.9679	0.5542	0.4450	0.5245
5	0.9258	1.1720	0.5725	0.3168	0.6220
6	0.8650	1.0423	0.5580	0.3792	0.5539
7	0.8650	1.0423	0.5580	0.3792	0.5539

AGE	1997	1998	1999	2000	2001
1	0.0001	0.0001	0.0062	0.0058	0.0048
2	0.0523	0.0027	0.0790	0.1543	0.1076
3	0.1794	0.6187	0.3061	0.3844	0.4973
4	0.6163	0.4926	0.4879	0.2254	0.5342
5	0.5234	0.9099	0.1511	0.4599	0.6694
6	0.5868	0.5248	0.3261	0.2842	0.5837
7	0.5868	0.5248	0.3261	0.2842	0.5837

AGE	2002	2003	2004	2005	2006
1	0.0001	0.0001	0.0003	0.0011	0.0001
2	0.0554	0.1515	0.0292	0.0830	0.0222
3	0.4083	0.5134	0.2553	0.3347	0.1305
4	0.6095	0.9661	0.7105	0.6275	0.3111
5	0.6334	0.9763	0.8381	0.7918	0.2272
6	0.6181	0.9694	0.7537	0.6726	0.2691
7	0.6181	0.9694	0.7537	0.6726	0.2691

Table K12. VPA estimates of spawning stock biomass (mt) for Georges Bank winter flounder, 1982-2006.

AGE	1982	1983	1984	1985	1986
1	204.	24.	57.	344.	113.
2	1218.	545.	364.	1153.	1642.
3	3609.	2920.	1299.	906.	2804.
4	4323.	3479.	2174.	1361.	743.
5	2329.	2757.	1630.	1184.	668.
6	1547.	1025.	1389.	330.	605.
7	2407.	3469.	2846.	507.	578.
Total	15637.	14219.	9759.	5786.	7153.

AGE	1987	1988	1989	1990	1991
1	22.	83.	26.	4.	34.
2	2032.	872.	1918.	670.	543.
3	2552.	2711.	1830.	3393.	2323.
4	1807.	1193.	1000.	1114.	2062.
5	525.	786.	380.	438.	533.
6	293.	278.	395.	152.	169.
7	616.	421.	315.	93.	394.
Total	7846.	6344.	5864.	5864.	6057.

AGE	1992	1993	1994	1995	1996
1	21.	37.	65.	158.	46.
2	1049.	413.	475.	710.	2356.
3	1288.	1665.	849.	705.	954.
4	1317.	738.	1014.	451.	622.
5	1036.	615.	345.	682.	343.
6	292.	446.	240.	214.	525.
7	262.	224.	313.	409.	686.
Total	5265.	4138.	3302.	3330.	5532.

AGE	1997	1998	1999	2000	2001
1	0.	0.	185.	57.	67.
2	1322.	1339.	1649.	2041.	1043.
3	3102.	2636.	1953.	2682.	2770.
4	618.	2376.	1526.	1863.	2186.
5	389.	288.	1767.	1108.	1507.
6	207.	229.	160.	1723.	743.
7	263.	106.	259.	2091.	762.
Total	5901.	6975.	7499.	11564.	9077.

AGE	2002	2003	2004	2005	2006
1	23.	10.	0.	0.	0.
2	907.	453.	402.	293.	166.
3	2099.	1678.	1384.	1028.	1245.
4	1941.	1874.	1177.	1235.	821.
5	1539.	1287.	888.	643.	776.
6	980.	896.	540.	396.	333.
7	1352.	2089.	1111.	746.	956.
Total	8842.	8288.	5502.	4339.	4297.

Table K13. VPA estimates of annual average fishing mortality rates on fully-recruited ages (ages 4-6) for Georges Bank winter flounder, 1982-2006.

Year	Average F	N Weighted	Biomass Wtd	Catch Wtd
1982	0.4886	0.4627	0.4742	0.4712
1983	0.4865	0.5047	0.4913	0.5123
1984	1.3197	1.2656	1.3206	1.3619
1985	0.9256	0.9319	0.9272	0.9330
1986	0.6505	0.6316	0.6496	0.6536
1987	0.8511	0.9451	0.9310	0.9624
1988	1.0346	1.1572	1.0965	1.2095
1989	0.9494	0.9363	0.9396	0.9367
1990	1.0492	1.0293	1.0367	1.0303
1991	0.6712	0.7123	0.7038	0.7161
1992	0.8737	0.8660	0.8719	0.8674
1993	1.0607	1.0463	1.0577	1.0508
1994	0.5616	0.5580	0.5587	0.5581
1995	0.3803	0.3810	0.3703	0.3889
1996	0.5668	0.5546	0.5576	0.5566
1997	0.5755	0.5877	0.5819	0.5898
1998	0.6424	0.5311	0.5398	0.5485
1999	0.3217	0.3398	0.3135	0.4113
2000	0.3232	0.2883	0.3040	0.3126
2001	0.5958	0.5856	0.5892	0.5905
2002	0.6203	0.6182	0.6197	0.6183
2003	0.9706	0.9694	0.9701	0.9695
2004	0.7674	0.7553	0.7636	0.7581
2005	0.6973	0.6750	0.6828	0.6800
2006	0.2691	0.2772	0.2704	0.2819

Table K14. Survey catchabilities estimated from the Georges Bank winter flounder VPA, 1982-2006.

INDEX	Survey	Age	Catchability	Std. Error	CV
1	US_Sp	1	0.9424E-05	0.2014E-05	0.2137E+00
2	US_Sp	2	0.4403E-04	0.9294E-05	0.2111E+00
3	US_Sp	3	0.8762E-04	0.1582E-04	0.1806E+00
4	US_Sp	4	0.1399E-03	0.2104E-04	0.1504E+00
5	US_Sp	5	0.1723E-03	0.1937E-04	0.1125E+00
6	US_Sp	6	0.2048E-03	0.3448E-04	0.1684E+00
7	US_Sp	7	0.1225E-03	0.2674E-04	0.2182E+00
8	Can_Sp	1	0.1407E-04	0.6582E-05	0.4677E+00
9	Can_Sp	2	0.3794E-04	0.1448E-04	0.3817E+00
10	Can_Sp	3	0.4976E-04	0.1898E-04	0.3813E+00
11	Can_Sp	4	0.1510E-03	0.4041E-04	0.2677E+00
12	Can_Sp	5	0.2004E-03	0.4413E-04	0.2202E+00
13	Can_Sp	6	0.1949E-03	0.4660E-04	0.2391E+00
14	Can_Sp	7	0.1555E-03	0.4427E-04	0.2847E+00
15	US_A0	1	0.6596E-05	0.2049E-05	0.3107E+00
16	US_A1	2	0.3275E-04	0.7362E-05	0.2248E+00
17	US_A2	3	0.9495E-04	0.2008E-04	0.2114E+00
18	US_A3	4	0.1860E-03	0.3307E-04	0.1777E+00
19	US_A4	5	0.2662E-03	0.5880E-04	0.2209E+00
20	US_A5	6	0.2846E-03	0.6159E-04	0.2164E+00
21	US_A6	7	0.1961E-03	0.3912E-04	0.1995E+00

Table K15. Input data, based on 2002-2006 average values from the VPA, for the Georges Bank winter flounder SSB- and yield-per-recruit model (M = 0.2).

Age	Selectivity on F	Selectivity on M	Mean stock weights	Mean catch weights	Spawning stock weights	Proportion mature
1	0.0005	1	0.061	0.118	0.0607	0.00
2	0.1000	1	0.253	0.444	0.2528	0.44
3	0.4900	1	0.504	0.618	0.5040	1.00
4	1.0000	1	0.737	0.925	0.7367	1.00
5	1.0000	1	1.027	1.186	1.0271	1.00
6	1.0000	1	1.265	1.455	1.2654	1.00
7+	1.0000	1	1.814	1.814	1.8140	1.00

Table K16. Biological reference point estimates from a non-parametric yield- and SSB-per-recruit model and a parametric approach, using a Beverton-Holt stock recruitment model, for Georges Bank winter flounder.

Beverton-Holt model

F_{MSY}	0.33
MSY (mt)	7,500
SSB_{MSY} (mt)	27,000

Per-recruit model

$F_{40\%}$	0.25
MSY (mt)	3,400
SSB_{MSY} (mt)	15,500

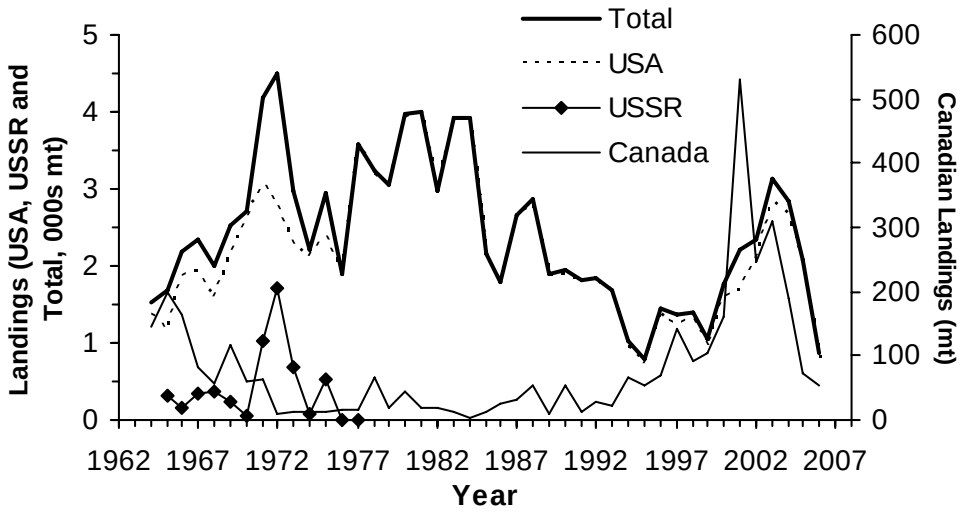


Figure K1. Landings of Georges Bank winter flounder during 1964-2006.

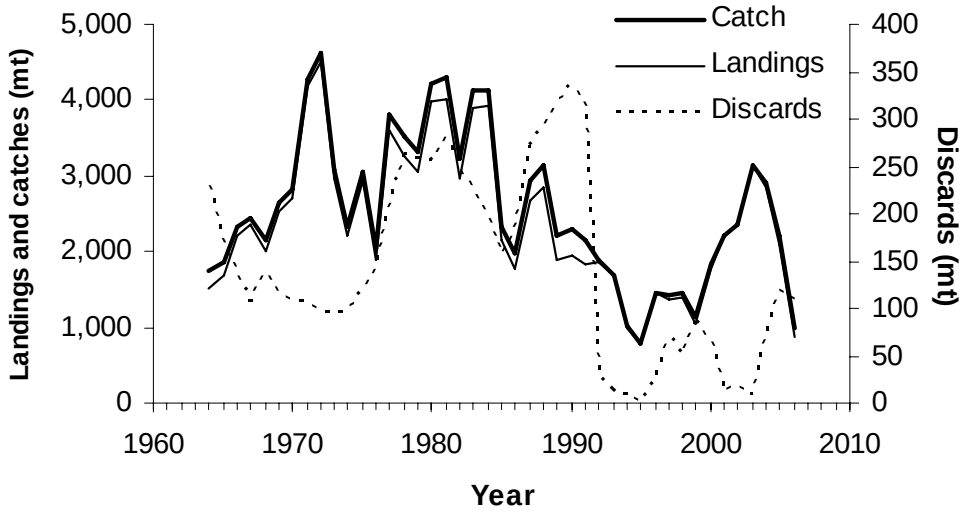


Figure K2. Landings, discards, and catches of Georges Bank winter flounder during 1964-2006.

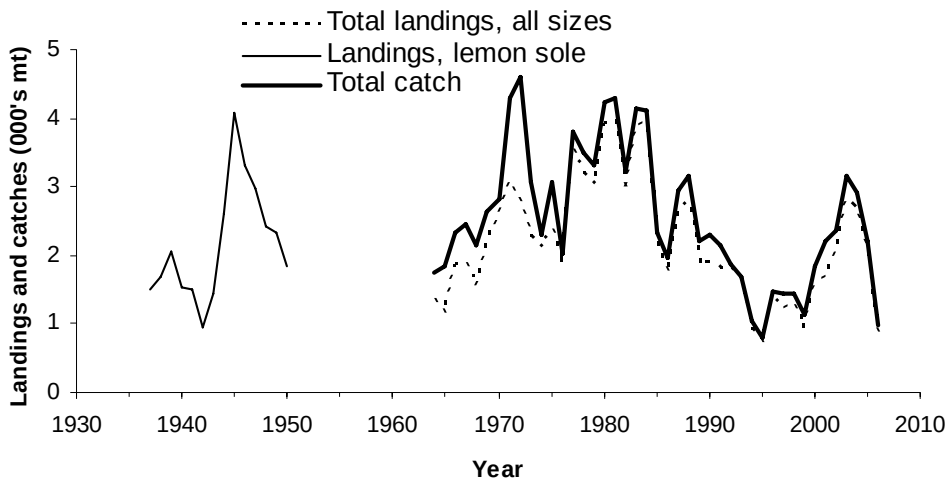


Figure K3. Historical landings of lemon sole (fish > 3 lbs) winter flounder from Georges Bank, during 1935-1950, in relation to total landings and catches of GB winter flounder during 1964-2006.

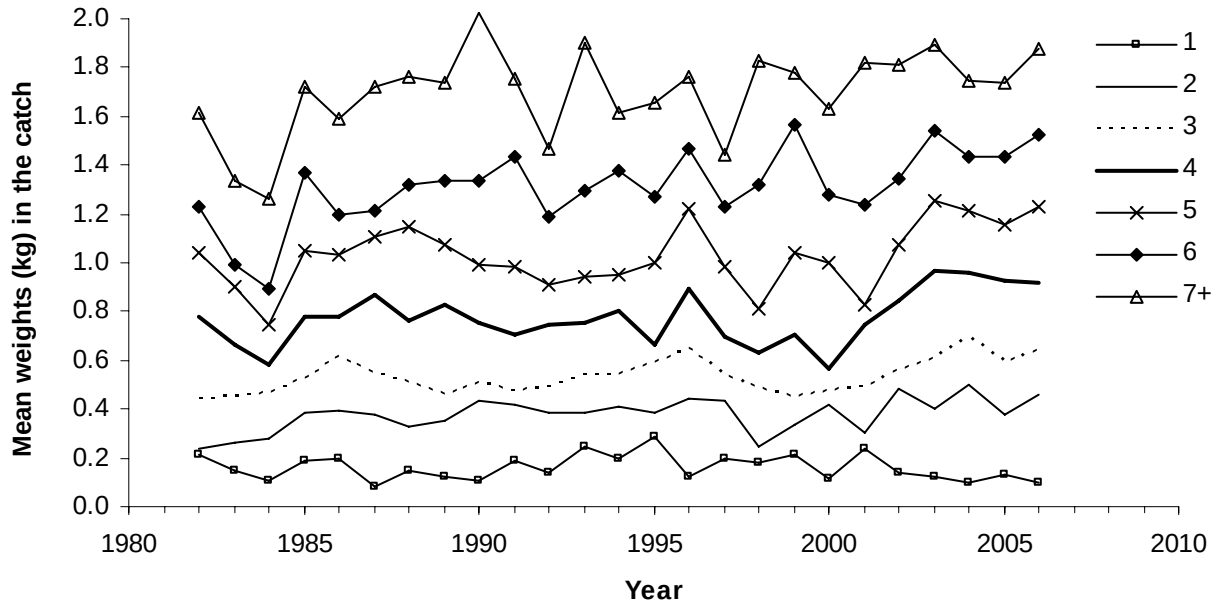


Figure K4. Trends in mean weights (kg) at age for the total catch of GB winter flounder, 1982-2006.

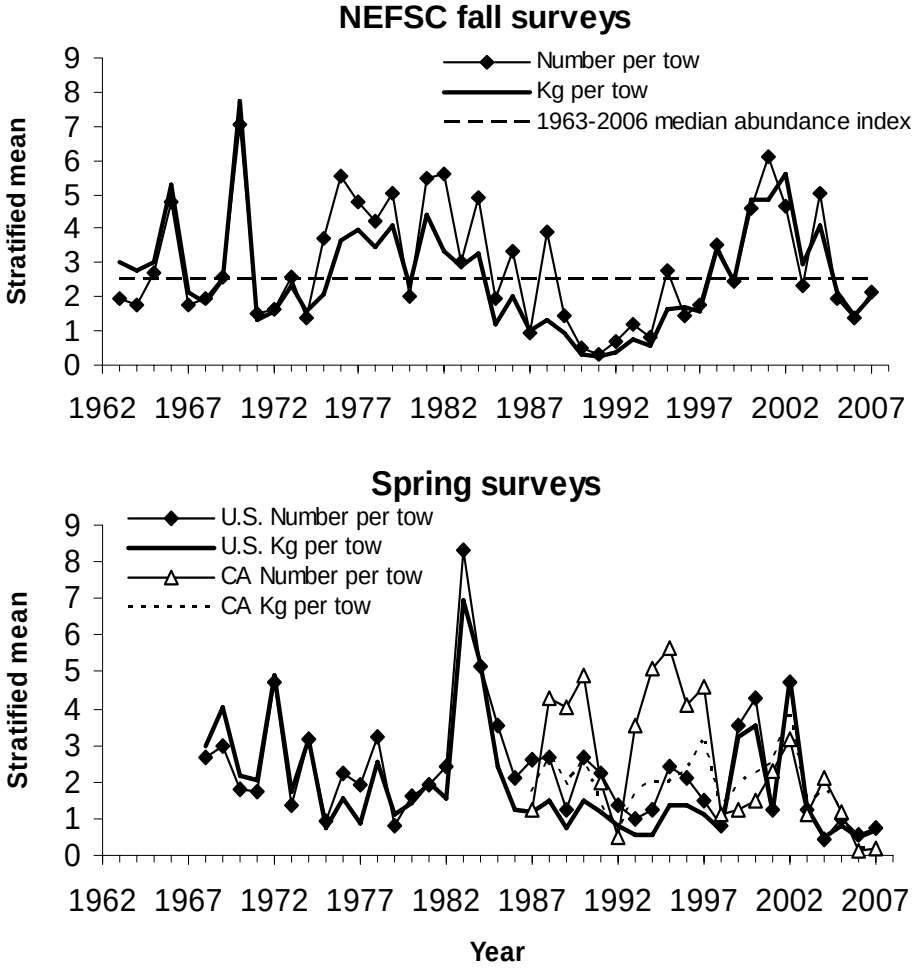


Figure K5. Relative biomass (stratified mean kg per tow) and abundance (stratified mean numbers per tow) indices for Georges Bank winter flounder caught during NEFSC fall (1963-2007) bottom trawl surveys and NEFSC spring (1968-2007) and Canadian spring (1987-2007, strata 5Z1-5Z4) bottom trawl surveys. NEFSC survey indices include strata 13-23 and were standardized for gear changes (weight = 1.86 and numbers = 2.02) and trawl door changes (weight = 1.39 and numbers = 1.46) prior to 1985.

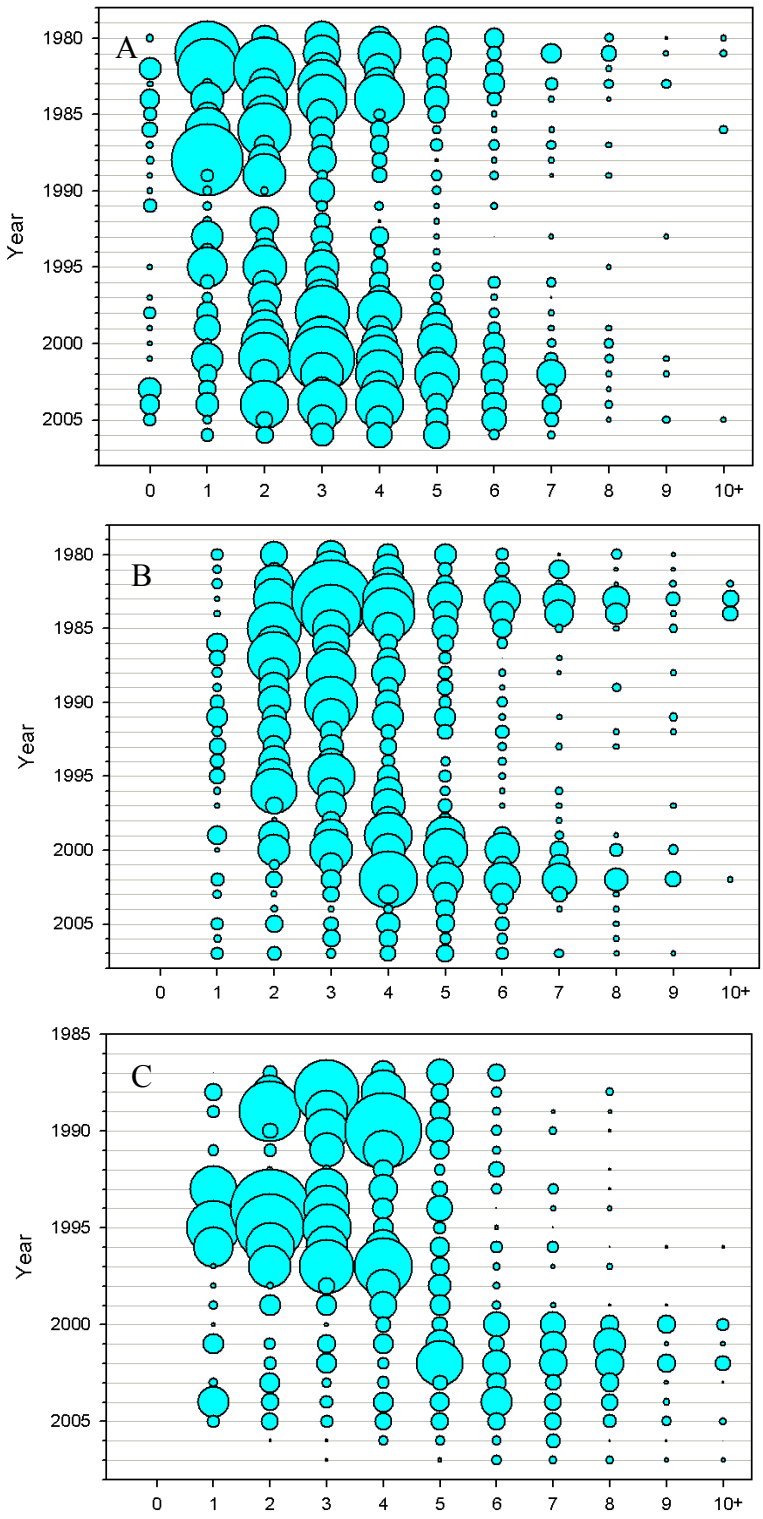


Figure K6. Stratified mean number per tow at age indices for (A) NEFSC fall bottom trawl surveys (1963-2007), (B) NEFSC spring surveys (1968-2007) and (C) CA spring surveys (1987-2007). NEFSC survey indices include offshore strata 13-23 and CA spring surveys in clued strata 5Z1-5Z4.

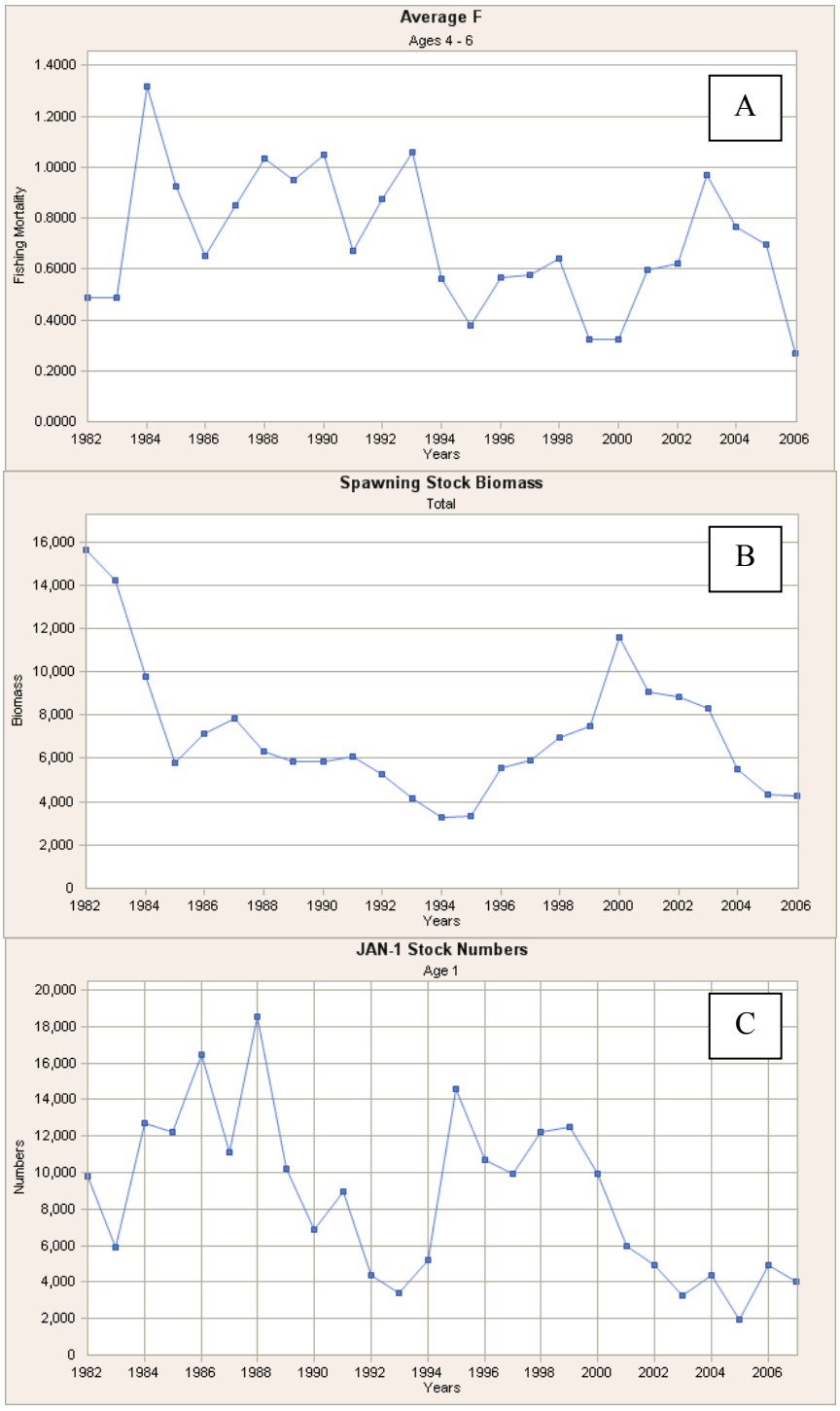


Figure K7. Annual trends in VPA estimates of Georges Bank winter flounder (A) average fishing mortality rates on fully-recruited ages 4-6, (B) spawning stock biomass (mt) and (C) age 1 recruitment (numbers, 000's) during 1982-2006.

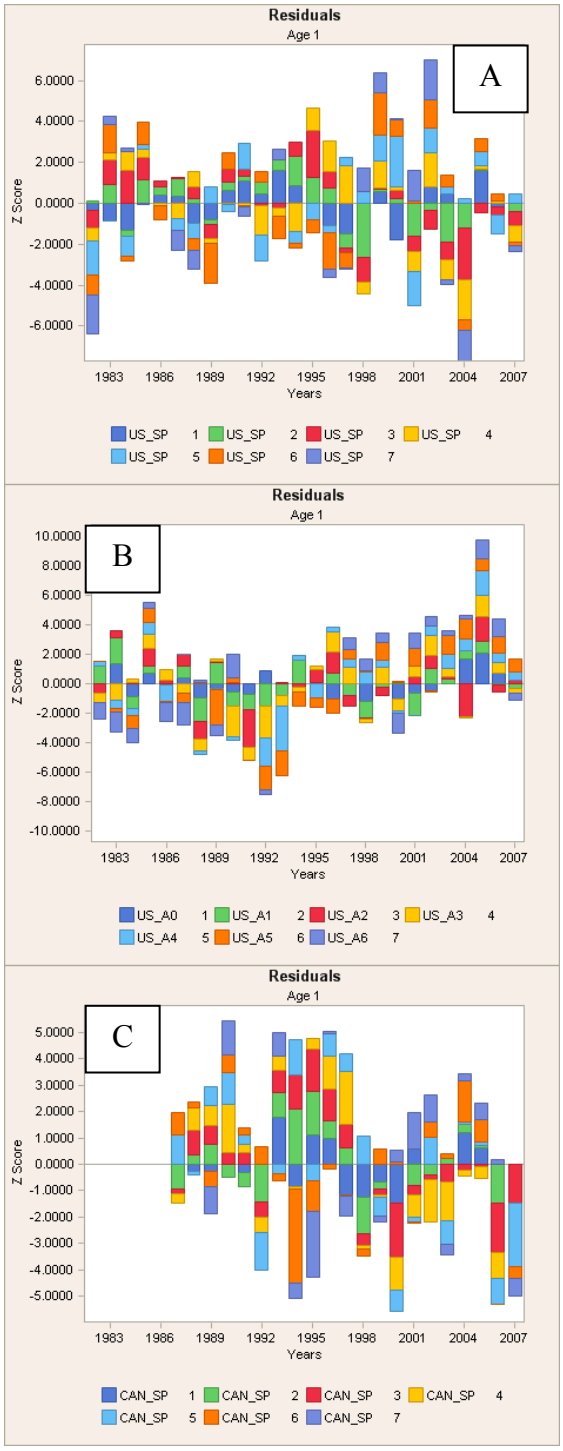


Figure K8. Residual patterns NEFSC (A) spring and (B) autumn bottom trawl survey indices (ages 1-7, 1982-2006), and the (C) Canadian spring bottom trawl survey indices (ages 1-7, 1987-2006) used to calibrate the VPA.

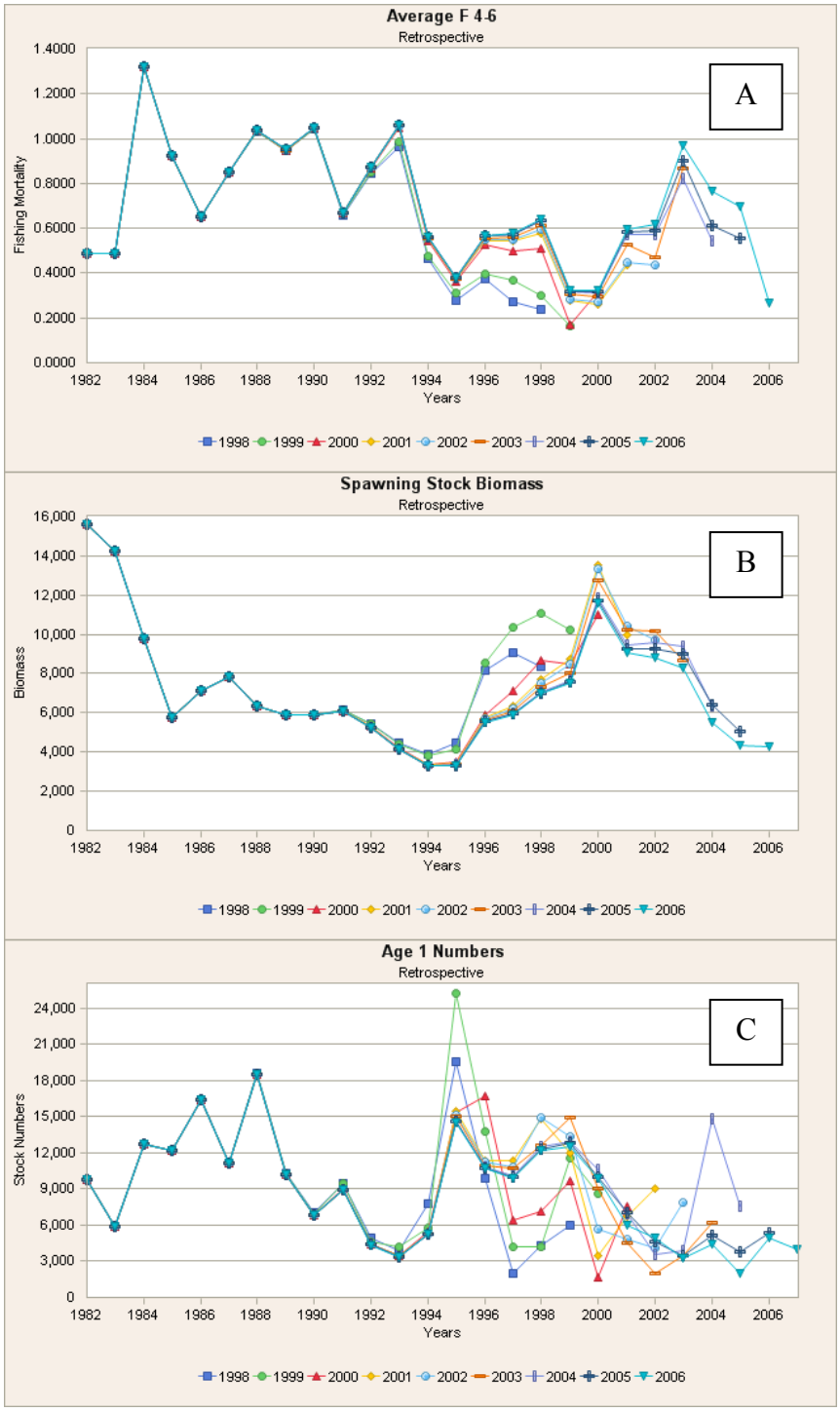


Figure K9. Retrospective analysis of (A) average F (ages 4-6), (B) spawning stock biomass (mt), and (C) Age 1 recruitment (numbers, 000's) during 1993-2006.

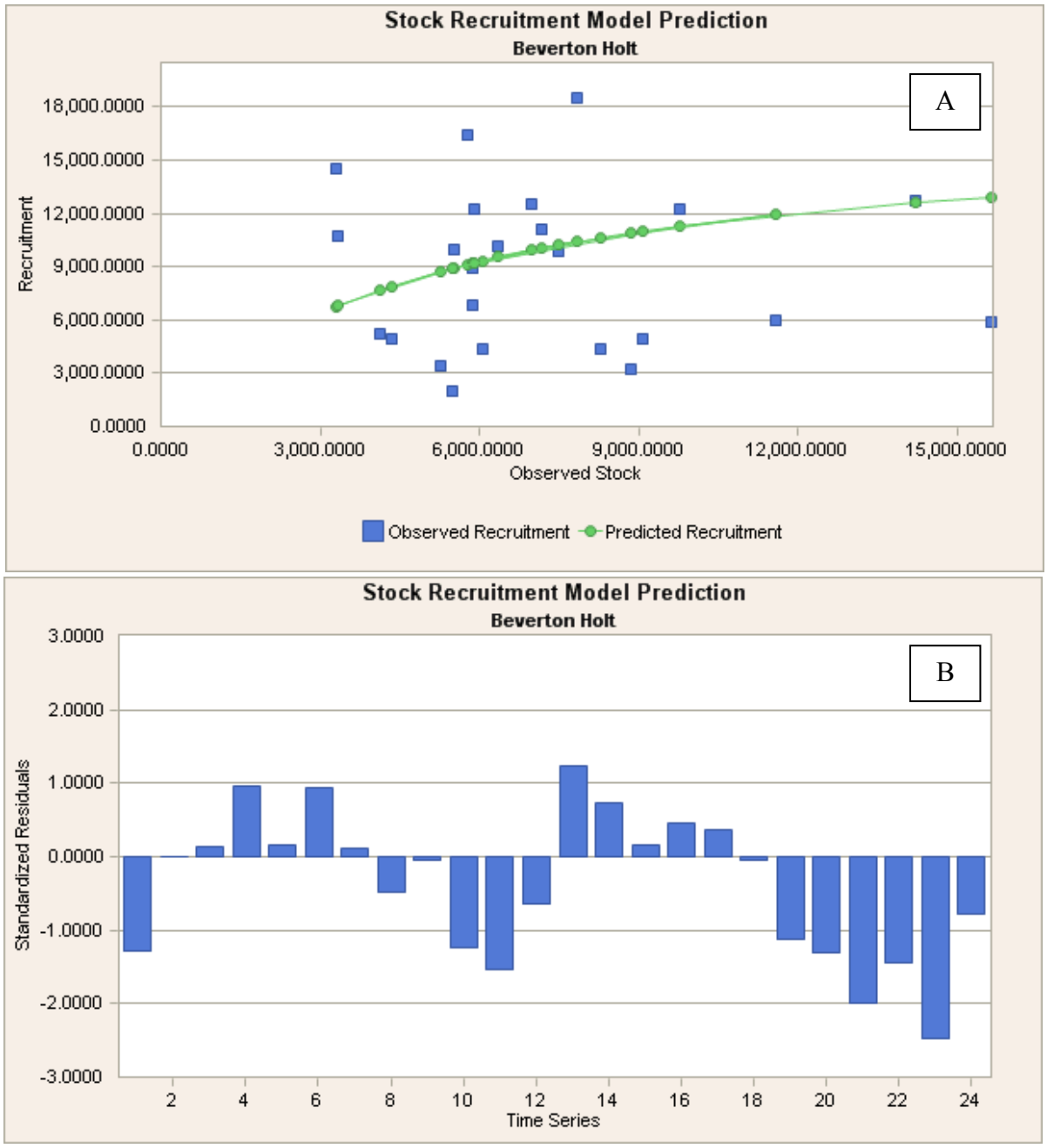
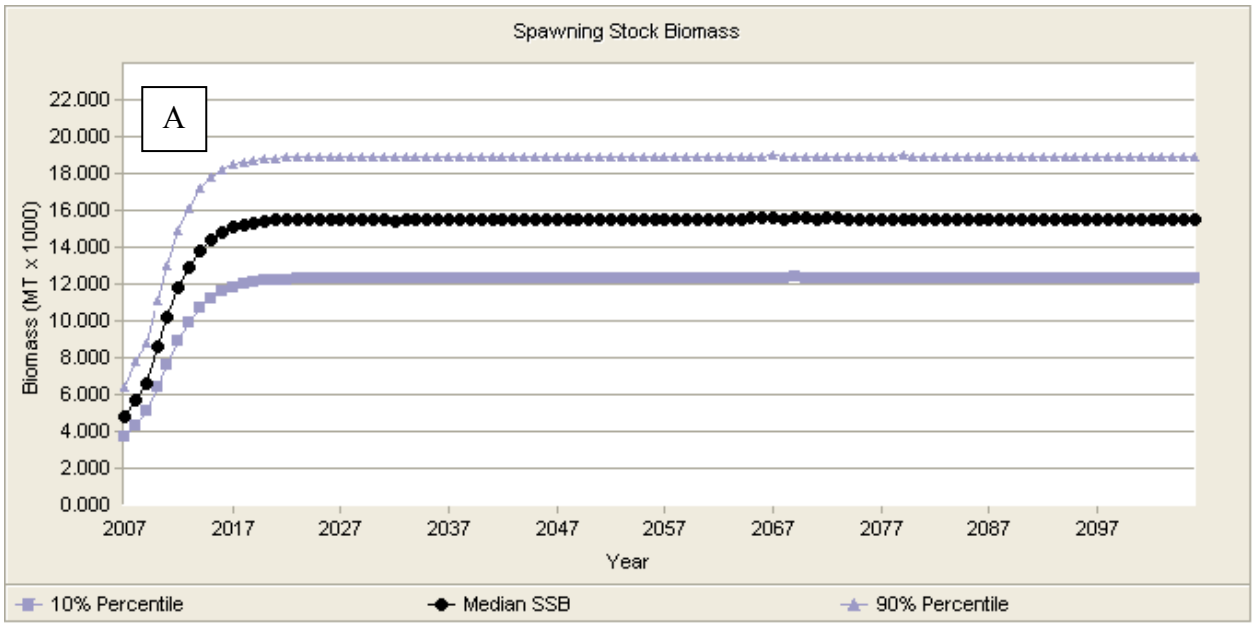


Figure K10. The (A) predicted Beverton-Holt stock recruitment relationship estimated for Georges Bank winter flounder, for the 1981-2005 year classes, and (B) standardized residuals from the model.



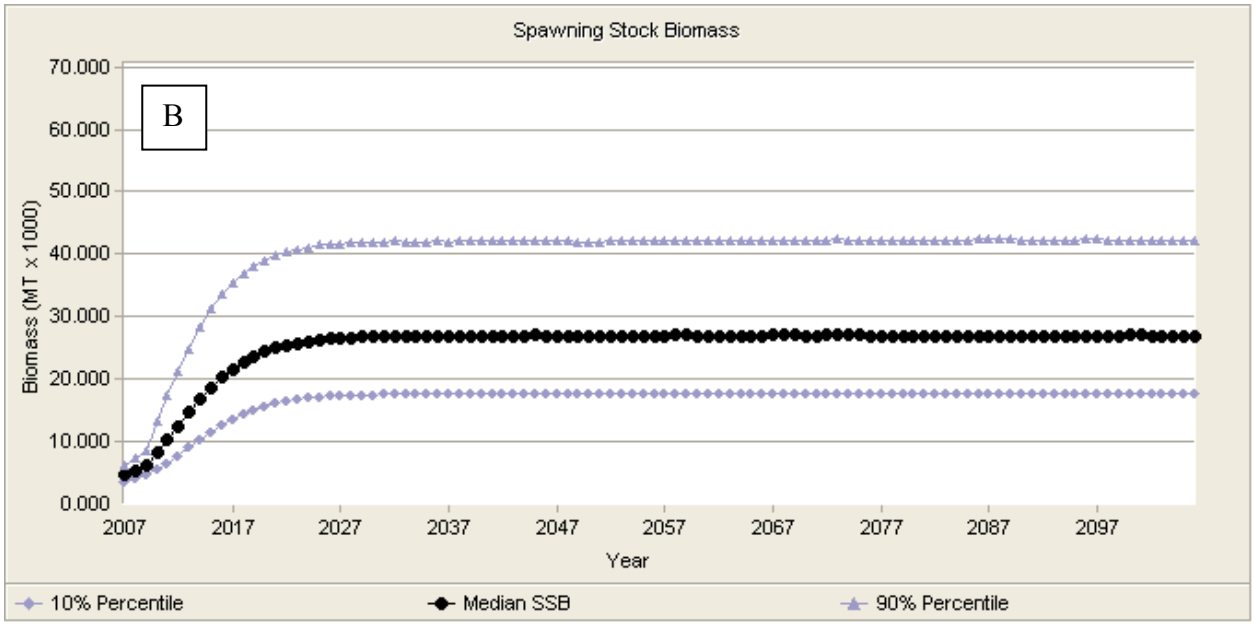


Figure K11. Median SSB_{MSY} estimates for 100-year projections at (A) a constant harvest rate of $F_{40\%}$ (= 0.25) and (B) a constant harvest rate of F_{MSY} (= 0.33). Median SS_{BMSY} equals 15, 500 mt for scenario (A) and 27,000 mt for scenario (B).

7.0 Appendices

Table A.K1. Numbers of commercial lengths sampled, by year and market category, for Georges Bank winter flounder during 1982-2006.

Year	N lengths by market category					Sampling intensity (mt landed per 100 lengths)
	Unclassified (1200)	Lemon/XL (1201, 1204)	Large/Lg mix (1202, 1205)	Med/small (1203, 1206, 1207)	Total	
1982	350	724	1,019	807	2,900	101
1983		625	1,768	2,100	4,493	86
1984		518	1,435	902	2,855	137
1985	68	728	1,675	1,456	3,927	55
1986	124	389	1,125	1,184	2,822	61
1987		603	1,068	1,437	3,108	82
1988		478	1,034	1,447	2,959	91
1989		167	566	737	1,470	120
1990	399	27	1,285	1,758	3,469	51
1991	103	136	1,603	1,295	3,137	53
1992		131	1,420	1,483	3,034	56
1993		336	509	590	1,435	108
1994		183	632	556	1,371	66
1995		103	279	469	851	85
1996		370	484	138	992	138
1997		43	518	443	1,004	121
1998			79	403	482	269
1999	94		121	274	489	190
2000		486	160	697	1,343	118
2001	102	670	990	804	2,566	65
2002	274	699	1,458	424	2,855	74
2003	268	1,589	2,863	625	5,345	53
2004		1,579	4,643	188	6,410	41
2005	161	1,987	3,790	576	6,514	29
2006	100	1,978	3,196	293	5,567	14

Table A.K2. Georges Bank winter flounder discards (mt) for large mesh (codend mesh ≥ 5.5 in.) and small mesh (codend mesh < 5.5 in.) groundfish bottom trawl fisheries and the scallop dredge/trawl fisheries.

	Discards (mt)			
Year	Large mesh	Small mesh	Scallop dredge	Total
1964		112.1	118.4	230.6
1965		135.4	29.7	165.1
1966		118.9	18.2	137.1
1967		82.0	24.0	106.0
1968		74.1	65.9	140.0
1969		74.8	42.2	117.0
1970		72.6	36.8	109.4
1971		69.5	35.9	105.4
1972		61.4	36.7	98.1
1973		61.1	32.8	94.0
1974		59.7	38.3	97.9
1975		60.4	57.6	118.0
1976		48.8	93.0	141.9
1977		68.3	138.8	207.0
1978		77.0	184.9	261.9
1979		75.8	181.7	257.4
1980		83.1	171.6	254.7
1981		97.3	184.0	281.3
1982	11.4	72.3	162.6	246.3
1983	39.8	21.8	163.6	225.3
1984	47.3	3.3	144.5	195.1
1985	28.9	1.6	127.7	158.2
1986	23.3	1.6	156.6	181.5
1987	24.8	1.9	245.5	272.1
1988	28.3	6.4	258.3	293.0
1989	13.8	0.1	302.4	316.2
1990	15.7	0.0	322.3	338.0
1991	1.9	0.0	311.9	313.8
1992	8.5	0.0	20.3	28.8
1993	2.5	0.0	8.1	10.6
1994	2.3	0.9	6.4	9.5
1995	1.1	0.0	0.0	1.1
1996	8.3	0.0	17.4	25.7
1997	0.0	0.0	69.2	69.2
1998	0.1	0.0	51.5	51.7
1999	44.0	0.0	41.2	85.2
2000	16.7	0.1	48.2	64.9
2001	2.4	0.0	8.3	10.7
2002	3.1	0.0	16.5	19.7
2003	6.5	0.9	2.1	9.5
2004	46.6	15.4	7.3	69.3
2005	15.0	15.3	87.5	117.9
2006	26.3	14.9	68.8	110.0

Table A.K3. Summary of Georges Bank winter flounder discards (mt) estimated for large (codend mesh size ≥ 5.5 in.) and small mesh (codend mesh size < 5.5 in.) groundfish bottom trawl fisheries and the scallop dredge/trawl fisheries (limited permit category), 1964-2006. D/K represents discards of GB winter flounder/weight of all species kept. Discards were hindcast for: large mesh bottom trawl during 1982-1988; small mesh groundfish bottom trawls during 1964-1988; and scallop dredge during 1964-1991.

	Large Mesh Bottom Trawl			
YEAR	**N observed trips**	**D/K**	**Discards (mt)**	**CV**
1982			11.4	
1983			39.8	
1984			47.3	
1985			28.9	
1986			23.3	
1987			24.8	
1988			28.3	
1989	17	0.00069	13.8	0.59
1990	13	0.00070	15.7	0.80
1991	13	0.00017	1.9	0.37
1992	16	0.00045	8.5	0.60
1993	17	0.00014	2.5	1.69
1994	22	0.00019	2.3	0.65
1995	37	0.00011	1.1	0.52
1996	13	0.00076	8.3	0.81
1997	6	0.00000	0.0	
1998	5	0.00003	0.1	0.47
1999	7	0.00373	44.0	0.70
2000	17	0.00088	16.7	1.24
2001	26	0.00012	2.4	0.70
2002	48	0.00016	3.1	0.86
2003	107	0.00028	6.5	0.46
2004	154	0.00188	46.6	0.59
2005	569	0.00081	15.0	0.25
2006	303	0.00221	26.3	0.31

Table A.K3 (cont.)

	Small Mesh Groundfish Bottom Trawl			
YEAR	**N observed trips**	**D/K**	**Discards (mt)**	**CV**
1964			112.1	
1965			135.4	
1966			118.9	
1967			82.0	
1968			74.1	
1969			74.8	
1970			72.6	
1971			69.5	
1972			61.4	
1973			61.1	
1974			59.7	
1975			60.4	
1976			48.8	
1977			68.3	
1978			77.0	
1979			75.8	
1980			83.1	
1981			97.3	
1982			72.3	
1983			21.8	
1984			3.3	
1985			1.6	
1986			1.6	
1987			1.9	
1988			6.4	
1989	15	0.00001	0.1	0.87
1990	8	0.00000	0.0	
1991	8	0.00000	0.0	
1992	6	0.00000	0.0	
1993	1	0.00000	0.0	
1994	2	0.01141	0.9	0.00
1995	3	0.00000	0.0	
1996	2	0.00000	0.0	
1997	1	0.00000	0.0	
1998	1	0.00000	0.0	
1999	1	0.00000	0.0	
2000	5	0.00003	0.1	0.97
2001	7	0.00000	0.0	
2002	7	0.00002	0.0	0.82
2003	15	0.00010	0.9	0.85
2004	17	0.00363	15.4	0.89
2005	79	0.00279	15.3	0.64
2006	18	0.00461	14.9	0.77

Table A.K3 (cont.)

	Scallop dredge/trawl, Limited category permits			
YEAR	**N observed trips**	**D/K**	**Discards (mt)**	**CV**
1964			118.4	
1965			29.7	
1966			18.2	
1967			24.0	
1968			65.9	
1969			42.2	
1970			36.8	
1971			35.9	
1972			36.7	
1973			32.8	
1974			38.3	
1975			57.6	
1976			93.0	
1977			138.8	
1978			184.9	
1979			181.7	
1980			171.6	
1981			184.0	
1982			162.6	
1983			163.6	
1984			144.5	
1985			127.7	
1986			156.6	
1987			245.5	
1988			258.3	
1989			302.4	
1990			322.3	
1991			311.9	
1992	6	0.00101	20.3	0.98
1993	8	0.00030	8.1	3.06
1994	5	0.00156	6.4	0.91
1995	3	0.00004	0.0	0.00
1996	4	0.00331	17.4	0.00
1997	6	0.00951	69.2	0.78
1998	4	0.00677	51.5	1.51
1999	19	0.00124	41.2	0.59
2000	179	0.00209	48.2	0.14
2001	16	0.00203	8.3	0.21
2002	4	0.00305	16.5	0.56
2003	2	0.00024	2.1	0.00
2004	30	0.00045	7.3	0.28
2005	62	0.00186	87.5	0.28
2006	68	0.00119	68.8	0.37

Table A.K4. Number of observed trips, by fleet and quarter, included in the discard estimates of GB winter flounder, 1989-2006.

	Large mesh otter trawl					Small mesh groundfish otter trawl					Scallop dredge/otter trawl				
Year	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total
1989	2	8	3	4	17		3	10	2	15					0
1990	4	3	4	2	13		2	6		8					0
1991	8	1	1	3	13	1		7		8				1	1
1992	9	4		3	16			5	1	6	1	2	1	2	6
1993	4	10		3	17			1		1	2	2	2	2	8
1994	10	6	3	3	22		1		1	2		1	1	3	5
1995	18	9	5	5	37	2		1		3	1		2		3
1996	3	9		1	13	1	1			2	1	1	1	1	4
1997	3		3		6		1			1	1	2	2	1	6
1998	3		2		5	1				1		2	1	1	4
1999		2	2	3	7	1				1		4	12	3	19
2000	4	2	5	6	17	3			2	5		25	64	90	179
2001	8	5	6	7	26	2	3	1	1	7	16				16
2002	5	6	15	22	48		1	2	4	7			4		4
2003	28	33	22	24	107	3	4	5	3	15			1	1	2
2004	32	36	43	43	154		5	8	4	17	2		4	25	31
2005	157	212	82	118	569	19	23	14	23	79	6	5	40	21	72
2006	95	87	91	30	303	8	3	4	3	18	6	8	40	14	68

Table A.K5. Number of Georges Bank winter flounder lengths sampled from the discards of the bottom trawl and scallop dredge fisheries by fisheries observers during 1989-2006.

	N lengths sampled from discards	
Year	Bottom trawl	Scallop dredge
1989	70	0
1990	22	0
1991	5	0
1992	15	1
1993	5	3
1994	6	35
1995	11	0
1996	39	2
1997	1	417
1998	1	84
1999	2	17
2000	4	15
2001	1	0
2002	95	1
2003	92	1
2004	299	125
2005	420	807
2006	438	421
Total	1,526	1,929

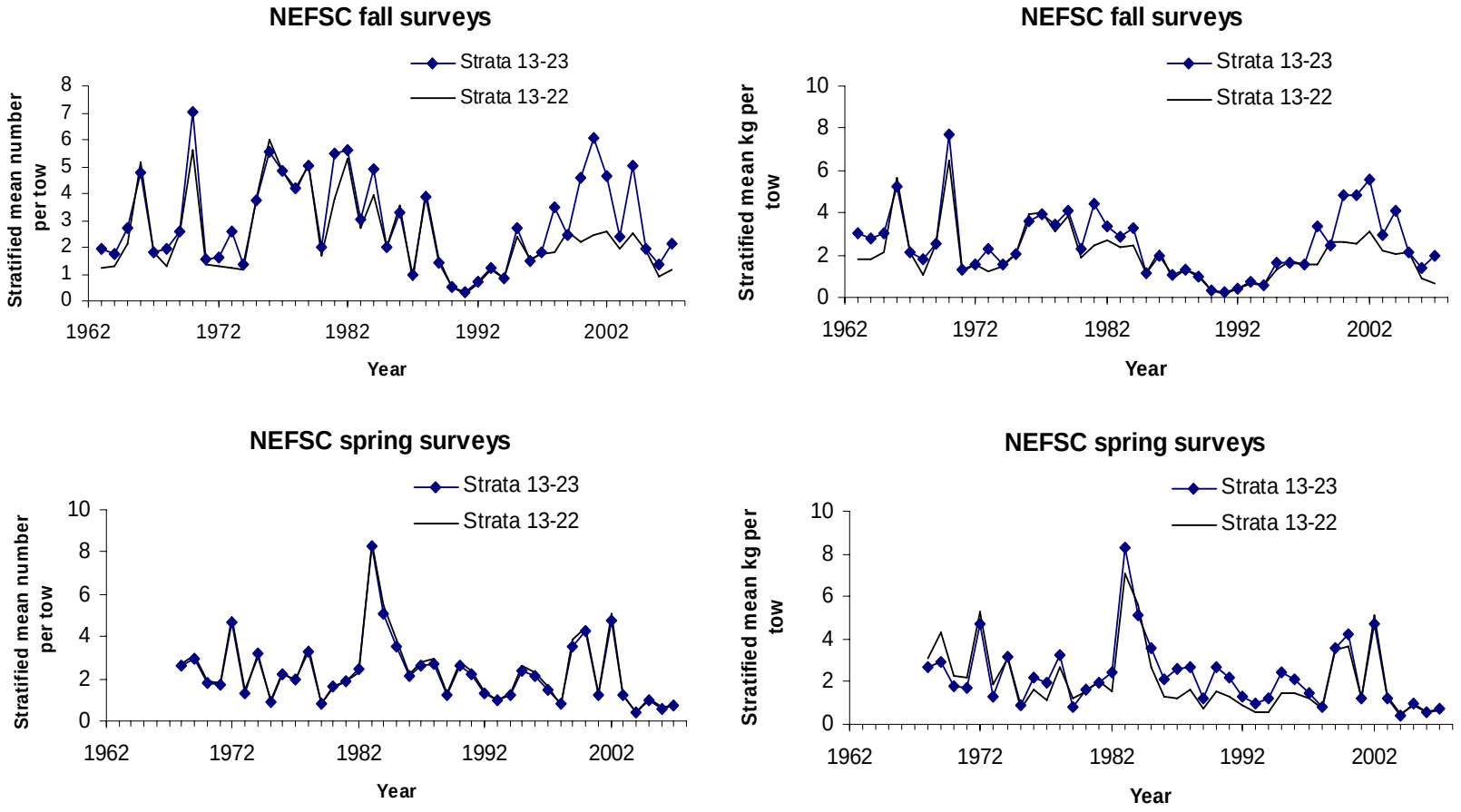


Figure A.K1. Relative biomass (stratified mean kg per tow) and abundance (stratified mean numbers per tow) indices for Georges Bank winter flounder caught during NEFSC spring (1968-2007) and autumn (1963-2007) bottom trawl surveys. Survey indices were computed using data from strata 13-23 versus strata 13-22 and standardization coefficients for gear changes (weight = 1.86 and numbers = 2.02) and trawl door changes (weight = 1.39 and numbers = 1.46) were applied to all sets of survey indices.